PATENT SPECIFICATION

1 270 821

DRAWINGS ATTACHED

1 270 821

(21) Application No. 11155/69 (22) Filed 3 March 1969
(23) Complete Specification filed 24 Feb. 1970
(45) Complete Specification published 19 April 1972.
(51) International Classification G01V 3/10
(52) Index at acceptance
G1N 25X 284 392 395 614 625 654 659 701

(72) Inventors DENNIS WILLIAM PASCOE
GEOFFREY MAYO

(54) FERROMAGNETIC METAL DETECTOR

(71) We, LOMA ENGINEERING LIMITED, a British Company formerly of 2 Industrial Site, 8 Winstanley Way, Basildon, Essex, and now of Springfield Works, Springfield Lane, Weybridge, Surrey, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following Statement:

This invention relates to a detector head for detecting ferromagnetic material when the material is moved relative the head. The term "detecting" is used in the sense of generating a measurable electrical signal in response to said movement.

The invention is primarily concerned with the detection of ferric material contained in, or shielded by a non-ferric metal container, for example, it can be used to detect the presence of iron or steel foreign bodies in aluminium foil wrapped food packages. However, the detector head can be used generally to detect ferromagnetic materials which are moved through the detector head above a predetermined minimum velocity.

According to the present invention a detector head for detecting ferromagnetic material when the material is moved along a path through the head, comprises a plurality of permanent magnets having like pole faces arranged opposite and spaced apart from each other, the pole gap or gaps defining a detection zone in said path, means for maintaining the magnets in said arrangement and a detection coil surrounding said detection zone and in which an electrical signal may be induced due to movement of the material through the zone, the axis of the coil being parallel to said path, and the strongest magnetic field of the magnets being conterminous with, and substantially parallel to said path and surrounded by the detection coil.

In a preferred embodiment a plurality of substantially U-shaped permanent magnets are arranged in separate rows on each side of the detection zone, the North and the South poles of the magnets on each of said sides being contiguous, and the like pole faces of the magnets on one of said sides being opposite and spaced apart from the corresponding like poles of the magnets on the other of said sides, the arrangement being such that the region of maximum magnetic flux lies within the detection zone where the magnetic field is substantially parallel to said path. The detection coil consists of a plurality of windings and terminals for connection to an indicating or measuring device. The coil is located between the arms of the magnets on each side of the detection zone, but in an alternative arrangement the permanent magnets are arranged round the complete periphery of the coil. The magnets are maintained in the said arrangement by a supporting structure preferably made from non-magnetic material and which is such as to prevent like poles from moving apart due to mutual forces of repulsion. The structure includes a non-magnetic sleeve defining an aperture through which articles to be detected may be passed, the pole faces of the magnets on each side of the detection zone being separated by the sleeve. The detection coil and the permanent magnets are preferably contained in a housing constructed from ferromagnetic material and having openings therein co-extensive within said sleeve. The thickness of the material used for the housing is preferably sufficient to shield its exterior from the magnetic fields due to the permanent magnets, and to prevent incorrect detection signals being induced in the coil due to moving ferromagnetic objects external to the housing.

Under optimum conditions, there is a magnetic field substantially axial to the axis of the sleeve within the detection zone.

Articles are passed through the centre of said zone to offset the generation of spurious signals in the detection coil due to eddy currents which may be induced in non-ferrous metal articles passed through the detector head in a region where the magnetic field is not substantially unidirectional.

The indication or measurement device for connection to the terminals of the detector head preferably comprises a high gain DC amplifier for providing an amplified signal either for measurement, or supply to a threshold detector used as a trigger circuit. When the threshold detector is used, it is conneced to a relay driver circuit for operating a relay having contacts connected to an indicator or a reject device for rejecting an article in which a foreign ferromagnetic body has been detected. The signal from the detector head is supplied to the high gain DC amplifier, and an amplified output signal is thereby fed to the input of the tnresnold detector. The response of the threshold detector to a minimum received signal is preferably adjustable. The output of the threshold detector is fed to the base of a transistor used as the relay driver circuit and having its emitter and collector in series with a relay coil.

An example of the invention is described with reference to the drawings accompanying the Provisional Specification in which,

Figure 1 is a simplified drawing showing an arrangement of magnets and a detection coil for a basic detector head,

Figure 2 schematically illustrates in perspective, parts of a detector head based on the arrangement shown in Figure 1,

Figure 3 is a perspective view of a sleeve used in the detector head of the invention,

Figure 4 is a front elevation through a housing of the detector head shown in Figure 2,

Figure 5 is a plan view of the arrangement shown in Figure 4,

Figure 6 is a schematic circuit diagram of a suitable control for use with the detector head,

Figure 7 illustrates the construction of integrated circuits used in the control, and

Figure 8 is a circuit diagram of a suitable power supply for the control, and the drawing accompanying the Complete Specification, referred to herein as Figure 9, which shows the basic detector head of Figure 1 with compensating coils.

The detector head described below is particularly useful for detecting the presence of ferromagnetic materials surrounded by a non-ferromagnetic metal container, e.g. it can be used to detect iron or steel foreign bodies within aluminium foil-wrapped food packages passing through the head. However, the invention is capable of detecting the presence of a moving ferromagnetic body whether or not it is encased or shielded by non-magnetic, metallic or non-metallic materials.

Figure 1 illustrates two permanent U-shaped magnets 2 and 4 oppositely arranged on either side of a gap 6 with their like poles (North and South) facing one another. A detection coil 8, shown sectionally, passes around the gap 6 in a plane perpendicular to the sheet of the drawing and has terminals (not shown) for connection to an indicating, measuring, or control device (not shown. The magnetic field between the magnets 2 and 4 in the plane of the drawing is generally indicated by the lines within the gap 6, which lines are the imaginary lines of force commonly used for showing a magnetic field. The field illustrated omits the earth's magnetic field for the sake of clarity, the latter field being negligible.

With this arrangement of permanent magnets, the maximum magnetic flux exists in a region mid-way between the illustrated sections of the coil 8, i.e. where the lines of force are most concentrated and lie substantially parallel with a path passing centrally between the magnetic poles (from one side to the other). This region is hereinafter known as a detection zone.

Figure 2 illustrates a more practical arrangement than Figure 1, and having magnets generaly indicated at *2* and *4*, detection coil 8, and pole gaps 6 defined by a sleeve 10 of rectangular cross-section. In this arrangement, permanent U-shaped magnets *2* and *4* are arranged in two oppositely facing rows, the detector coil 8 being located between the arms of the magnets and surrounding the sleeve 10 made from non-magnetic material. For the sake of clarity, Figure 2 omits a structure for securing the magnets in the position shown, as without such a structure the repulsive magnetic fields due to opposite like pole faces would cause the magnets to move apart.

Magnets *2* and *4* are arranged conterminously in two rows on each side of a detection zone which extends in a central plane within the sleeve 10 over a width from the first to the last magnetic poles in each row. The magnets in each row are contiguous with adjacent like poles, and the like pole faces of magnets *2* are arranged opposite, and spaced apart from the corresponding like pole faces of the magnets *4*.

The combined fields of the U-shaped magnets form a region of maximum magnetic flux containing substantially parallel lines of magnetic force within said detection zone, the lines lying substantially parallel with a line drawn through the North and South poles of the magnets. With identical magnets, in a symmetrical arrangement, this combined field occurs across the width of

the sleeve 10 and at its geometric centre.

Alternative arrangements having opposite like and unlike poles, e.g. C-shaped magnets sequentially arranged in rows with opposing North and South poles, would provide a magnetic field between the pole gap perpendicular to that existing in the arrangement of Figure 2. This is an unsatisfactory arrangement since a metalic object passing through the transverse field would have eddy currents induced in it leading to spurious signals in the detector coil if, for example, it was only required to detect ferromagnetic bodies in aluminium containers.

In the embodiment shown by Figure 2, the number of magnets is arbitrary depending on the size of an object to be detected (it must pass through the sleeve 10), and the limit of required response (minimum size and velocity of detected object). Two tunnel-shaped magnets may be used in place of the plurality of magnets illustrated by Figure 2, but the latter are generally preferred due to their commercial availability. Permanent magnets are preferable to electromagnets since the latter require a high current source, and if the source is AC a filter network must be connected to the terminals of the detection coil.

The detector coil 8 comprises, for example, 2000 turns of copper wire wound on a former, the former being part of the sleeve 10. A suitable sleeve is illustrated by Figure 3 and contains cut-out sections 12, 14, 16 and one obscured by the drawing, and channels 20 and 22. These sections and channels make up the former for the detection coil. The sleeve 10 also comprises bars or strips 24, 26, 28 and 30 on the outside and transverse to the width of the sleeve, which bars define channels 32, 34, 36 and 38 in which the poles of the U-shaped magnets are located as shown in Figure 4. The sleeve 10 is constructed from non-magnetic material of sufficient strength to allow the magnets to be anchored thereon by a suitable structure. The structure retains the magnets in their correct position against their mutual forces of repulsion.

Figure 4 is a front elevation through a detector head assembly showing a suitable structure for retaining the magnets. Panels 40 and 42 are spaced apart from the sleeve 10 by the permanent magnets *2* and *4*, the side panels and the sleeve being held in position by studding 44 and 46 on either side of the sleeve. In practice, the magnets are slid into the channels 32, 34 and 36, 38 between the sleeve and side panels 40 and 42 which are held in place by the studding 46 and 44. Once inserted, the magnets are potted in a thermo-setting resin and secured by screwing up nuts 48, 50, 52 and 54 on the studding. The thermo-setting resin once set relieves some of the stresses on the magnet clamping structure and assists in preventing the magnets from moving apart during use of the detector head.

A sleeve 60 of rectangular cross section, for example, made from plastic may be inserted in the sleeve 10 to prevent articles passing through the rectangular aperture from bearing against the inside of sleeve 10. The side panels 40 and 42, the studding 44 and 46, the nuts 48, 50, 52 and 54 are made from non-magnetic materials.

The coil 8 is connected to terminals 56 and 58 to which a detection circuit may be attached as described below.

The detector head is preferably encased by a substantial shielding of ferromagnetic material, e.g. quarter inch mild steel plate welded at the corners and having one lid to allow assembly. The intense magnetic fields generated by the permanent magnets *2* and *4* require complete screening to off-set stray signals being induced in the detector coil due to ferromagnetic objects moving past the exterior of the detector head.

The aperture through the sleeve 10 is of sufficient cross-section to allow articles to be detected to be passed through the sleeve, and is ideally just large enough to provide a small peripheral clearance and thereby keep the detector head assembly compact. With a symmetrical arrangement, i.e. of magnets and grouped around a detection zone, articles wrapped in non-magnetic metallic foil are preferably passed through the geometric centre of the coil 8. If such articles are passed through the head widely off centre of the coil, e.g. an article of small cross section is passed through and on one side of a sleeve having large cross section spurious readings may be generated in the coil. This is due to the curvature of the magnetic field on either side of the detection zone containing the maximum magnetic flux leading to the generation of eddy currents in the foil wrapping. It is essential in detecting the presence of ferromagnetic bodies in articles wrapped in say, alumium foil, to have a magnetic field substantially in the same direction as the path of movement of the article through the detector head. Eddy currents are thereby minimised in non-magnetic metal wrappings which may surround the article.

Figure 5 is a plan view of the detector head shown in Figure 4, the same reference numerals identifying the same parts. Additional studding 45 and 47 is shown in Figure 5, which is provided with nuts (not shown) as with studding 44 and 46 for securing the magnets *2* and *4* on their supporting structure.

The function of the detector head depends generally on Faraday's law of magnetic induction, and in particular on the arrangement of the magnetic field within the detec-

tion zone relative the path of movement of an article passed through said zone. Referring to Figure 1, the maximum magnetic flux is shown by the concentrated lines of force mid-way between the magnets 2 and 4. These lines are substantially parallel over a short distance in the detection zone and lie in the direction of the path of an article which is passed through the coil 4. Since the magnetic field is parallel to said path, eddy currents are minimised in metallic articles passing through the detection zone. Thus, only a ferromagnetic body passing through the detection zone will be polarized due to the magnetic field, and since the body is moving a signal will be induced in the coil 4. If the ferromagnetic body is surrounded by a non-magnetic metallic wrapping, e.g. an aluminium foil wrapped food package containing a foreign body made of iron, the iron body will be detected by the coil 4. No signal is generated by the aluminium foil alone if a food package containing no ferromagnetic foreign body is passed through the coil 4.

As previously mentioned the articles to be detected are preferably passed through the centre of the detection zone to minimize eddy currents, since these could be detected in say aluminium foil wrappers due to curvature of the magnetic field at the side of the detection zone. In practice, the aperture through the detector head, i.e. the cross-section of the sleeve 60 in Figure 4 is designed to just accommodate the articles being detected. This ensures a central disposition of articles passed through the head, for examples, on a conveyor belt. If a conveyor belt is used, a rejection system may be placed after the head for rejecting articles in which a ferromagnetic body has been detected. The rejection system may be, for example, an air solenoid valve controlled by the control circuit described below, for blasting an article from the belt. Alternatively, a conventional plough or a mechanical reject arm may be actuated on receipt of a signal from the control circuit. With large articles, e.g. sacks of flour, a marker device may be used to spray or print a visible mark on a sack containing a ferromagnetic foreign body.

The control circuit illustrated by Figure 6 is of a typical construction to suit the detector head, and therefore, only a brief description will be given. The choice and function of components used in this circuit will be apparent to those skilled in the electronic art.

Terminals 62 and 64 are provided for connection to the terminals 56 and 58 (Figure 4) of the detector coil, and feed a detection signal to the input of a high gain D.C. aomplifier 66. A preset potentiometer 68 is provided to compensate for the small offset voltage of the integrated circuits (i.e. the slight difference in the two inputs required for zero balanced output, which varies for each integrated circuit). The output of amplifier 66 is coupled via a capacitor 70 to the input of a threshold detector 72. The threshold detection level 72 is adjustable by means of a potentiometer 74. The output of the threshold detector is coupled to the base of a transistor 76 in common emitter connection. The collector of transistor 76 is in series with a relay coil 78 having relay contacts 80. Transistor 76 is used as a relay driver or switch to energise the relay coil 78 when a detection signal from the detector head, amplified by amplifier 66, exceeds the preset threshold level of detector 72. The relay contacts may be used to operate a rejection system of the type mentioned above.

Amplifier 66 and threshold detector 72 are preferably integrated circuits of a type similar to that illustrated by Figure 7, which are commercially available units. The control circuit of Figure 6 may be mounted on a printed circuit supplied with edge connectors for easy assembly and maintenance.

Figure 8 shows a suitable power supply circuit for the control circuit of Figure 6, and includes a typical rectified A.C. supply with smoothing and zener diode voltage control. A transformer is used to step down the A.C. mains supply to a suitable working voltage.

The embodiment described above is particularly useful in the food industry to detect foreign ferromagnetic bodies in aluminium foil wrapped food packages passing through the detector head on a conveyor belt. By using powerful magnets with a suitable detector coil the belt speed can be reduced over the usual speeds encountered in known metal detector systems of the same type. For example, in one arrangement the belt speed may be as low as 10 ft./min. whereas known systems may run at a minimum speed of 100 ft/min. The minimum belt speed depends on the strength of the magnetic field in the detection zone, the design of the detector coil, the speed at which a ferromagnetic body passes through the magnetic field and the amplifier response. The above advantage is attributed to the particular arrangement of magnets and detector coil which gives a compact, high field strength detection zone, and the use of an integrating amplifier making use of the longer duration of small signals at low speeds.

The response of the control circuit may be simply adjusted and no balancing is required on installation of the detector system.

The exemplary embodiment may be generally used to detect ferric inclusions in foil

wrapped products, e.g. confectionery, cigarettes, and pharmaceutical tablets. Articles to be detected can pass through the head by a short distance gravity fall as an alternative to a conveyor belt.

By adjusting the threshold level of the control circuit shown in Figure 6, or calibrating a meter for use with the control circuit which meter is responsive to the detection signal, it is possible to provide a measure, or an estimation, of the size of a ferromagnetic body or inclusion passing through the detector head. Although the measure would only be approximate due to the shape and orientation of the ferromagnetic body and field variation, the invention can be adapted for sorting magnetic from non-magnetic materials, e.g. detecting ferrous matter in aluminium scrap, or sorting articles having associated therewith ferrous or ferromagnetic labels or bodies from other articles not associated with ferrous or ferromagnetic labels or bodies. The invention can also be used on a greater scale to provide a sufficiently large enough detection zone to be transversed by people, and hence provide a means of detecting metal armaments. This application may be used with advantage at airports or in private or military security areas.

In a further embodiment of the invention (shown by Figure 9) to reduce, or substantially eliminate, any stray pick-up or hum in the detection coil 8, a compensating coil is provided on each side of the detection coil outside the permanent magnet assembly comprising magnets *2* and *4*. Each compensating coil is wound with half the number of turns forming the detection coil 8 the turns in both compensating coils being wound in the opposite sense to the detection coil winding, for example, if the detection coil 8 is wound anti-clockwise, both compensating coils are wound clockwise. The compensating coils are wound in parallel planes to the plane of the detection coil 8 and enclose the same cross-sectional area as the detection coil. The compensating coils may be wound on the same former as the dctection coil 8 provided they are located outside the permanent magnet assembly.

The effect of these compensating coils is to cancel any stray pick-up or hum which exists outside the detector head causing flux to link both the compensating coils and the detection coil 8, the induced signals in the compensating coils and the detection coil being in opposite sense and thereby cancelling. Signals induced in the compensating coils by ferrous metal passing through the detector head are negligible since the field due to the permanent magnet assembly is far stronger in the region of the detection coil 8 than at its outer extremities. The detection signal is thereby substantially unaltered in the detection coil 8. This modification is advantageous when the detector head is used adjacent machinery in factories which can cause considerable interference.

WHAT WE CLAIM IS :—

1. A detector head for detecting ferromagnetic material when the material is moved along a path through the head, comprising a plurality of permanent magnets having like pole faces arranged opposite and spaced apart from each other, the pole gap or gaps defining a detection zone in said path, means for maintaining the magnets in said arrangement and a detection coil surrounding said detection zone and in which an electrical signal may be induced due to movement of the material through the zone, the axis of the coil being parallel to said path, and the strongest magnetic field of the magnets being counterminius with, and substantially parallel to, said path and surrounded by the detection coil.

2. A detector head as claimed in claim 1 in which a plurality of substantially U-shaped permanent magnets are arranged in separate rows on each side of the detection zone, the North and South poles of the magnets of each of said sides being contiguous, and the like pole faces of the magnets on one of said sides being opposite and spaced from the corresponding like poles of the magnets on the other of said sides, a region of maximum magnetic flux lying within the detection zone where the magnetic field is substantially parallel to said path.

3. A detector head as claimed in claim 2 in which the detection coil consists of a plurality of windings located between the arms of the U-shaped magnets.

4. A detector head as claimed in either claim 2 or 3 including further permanent magnets at the ends of each of said rows whereby all of the permanent magnets enclose the detection coil.

5. A detector head as claimed in any one of the preceding claims in which the magnets are maintained in the said arrangement by a supporting structure made of non-ferromagnetic material and which is such as to prevent like poles from moving apart due to mutual repulsive forces.

6. A detector head as claimed in claim 5 in which the structure comprises a non-ferromagnetic sleeve defining an aperture through which articles to be detected may be passed, the pole faces of the magnets on each side of the detection zone being separated by the sleeve.

7. A detector head as claimed in claim 6 including a housing of ferromagnetic material having an opening therein coextensive with the sleeve, the housing being

provided as a screen to reduce the magnetic field due to the permanent magnets external to the housing, and to prevent incorrect detection signals being induced in the coil due to moving ferromagnetic objects external to the housing.

8. A detector head for detecting ferromagnetic material when the material is moved along a path through the head substantially as herein described with reference to Figures 1-5 of the drawings accompanying the Provisional Specification.

9. A detector head as claimed in any one of claims 1-8, including compensating coils on each side of the detection coil, the compensating coils being wound in the opposite sense to the detection coil winding and the compensating coils being provided substantially to eliminate any stray pick-up or hum extraneous to the detector head by mutual cancellation of induced signals.

10. A ferromagnetic material detector comprising the detector head as claimed in any one of claims 1-9 and including a control circuit connected to the detection coil, said circuit being adapted to generate a control signal when ferromagnetic material passes through said detection zone.

11. A ferromagnetic material detector as claimed in claim 10 in which the control circuit includes a high gain D C amplifier connected to a threshold detector adapted as a trigger circuit.

12. A ferromagnetic detector as claimed in claim 11 in which the trigger circuit is connected to a relay driver circuit for operating a relay having contacts connected to either an indicator for indicating the presence of ferromagnetic material passing through said detection zone or reject device for rejecting ferromagnetic material or articles possessing ferromagnetic material passed through said detection zone.

13. A ferromagnetic detector as claimed in either claim 11 or 12 in which the threshold level of the threshold detector is adjustable.

14. A ferromagnetic detector comprising the detector head as claimed in any one of claims 1-9 and including an indicating or measuring device either to indicate the presence of ferromagnetic material passing through said detection zone or to provide a measure of the size of the ferromagnetic material passing through said detection zone.

15. A conveyor including the ferromagnetic material detector as claimed in any one of claims 10-14 and in which said path is travelled by a conveyor belt.

16. A conveyor including the ferromagnetic material detector as claimed in claim 12 in which said path is travelled by a conveyor belt and the reject device removes from the conveyor belt, ferromagnetic material or articles which include ferromagnetic material.

17. A conveyor as claimed in either claim 15 or 16 arranged and adapted to convey foil wrapped food packages through said detector head, those packages which contain ferromagnetic material being detected or detected and rejected.

18. A ferromagnetic material detector substantially as herein described with reference to the drawings accompanying the Provisional Specification.

19. A ferromagnetic material detector substantially as herein described with reference to the drawing accompanying the Complete Specification.

For the Applicants,
CARPMAELS & RANSFORD,
Chartered Patent Agents,
24 Southampton Buildings,
Chancery Lane,
London, W.C.2.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1972. Published at the Patent Office, 25 Southampton Buildings, London WC2A 1AY from which copies may be obtained.

1,270,821 PROVISIONAL SPECIFICATION

5 SHEETS

This drawing is a reproduction of the Original on a reduced scale.

SHEET 1

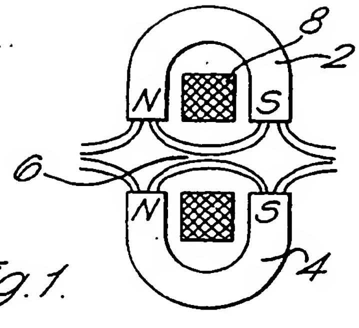

Fig.1.

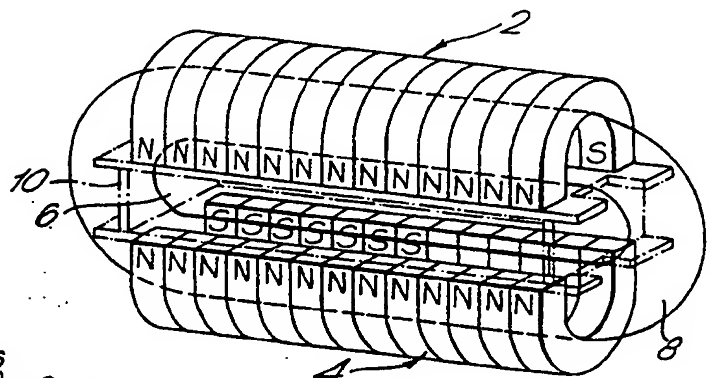

Fig.2

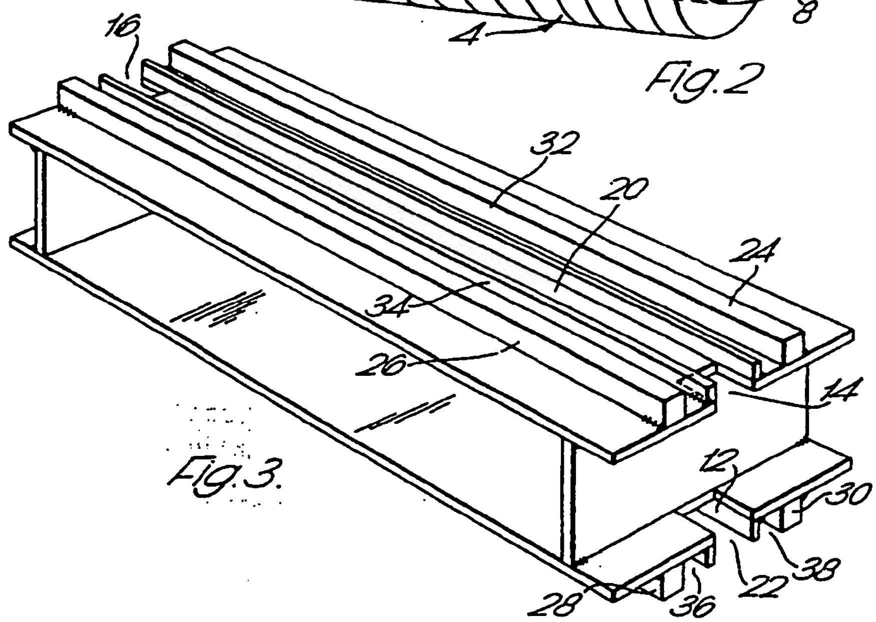

Fig.3.

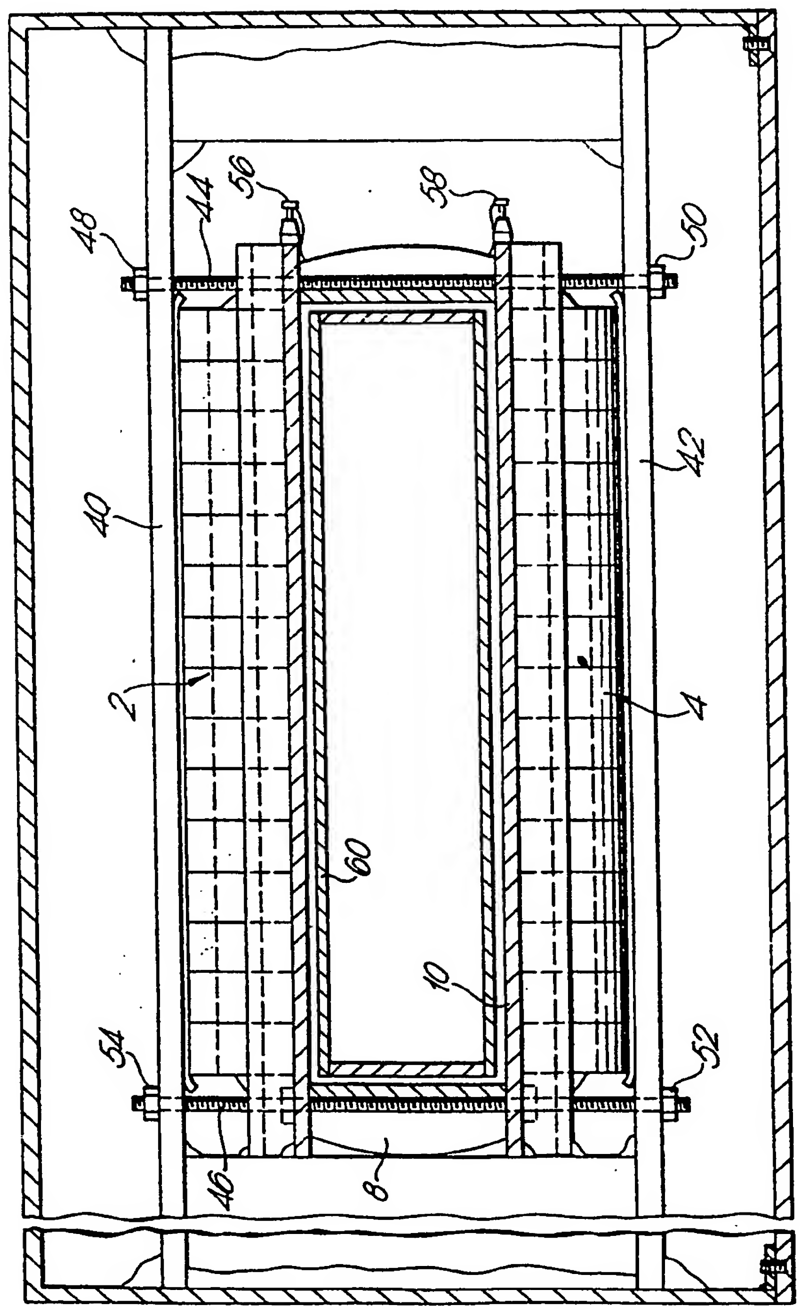

Fig.4.

1,270,821 5 SHEETS

PROVISIONAL SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.

SHEET 3

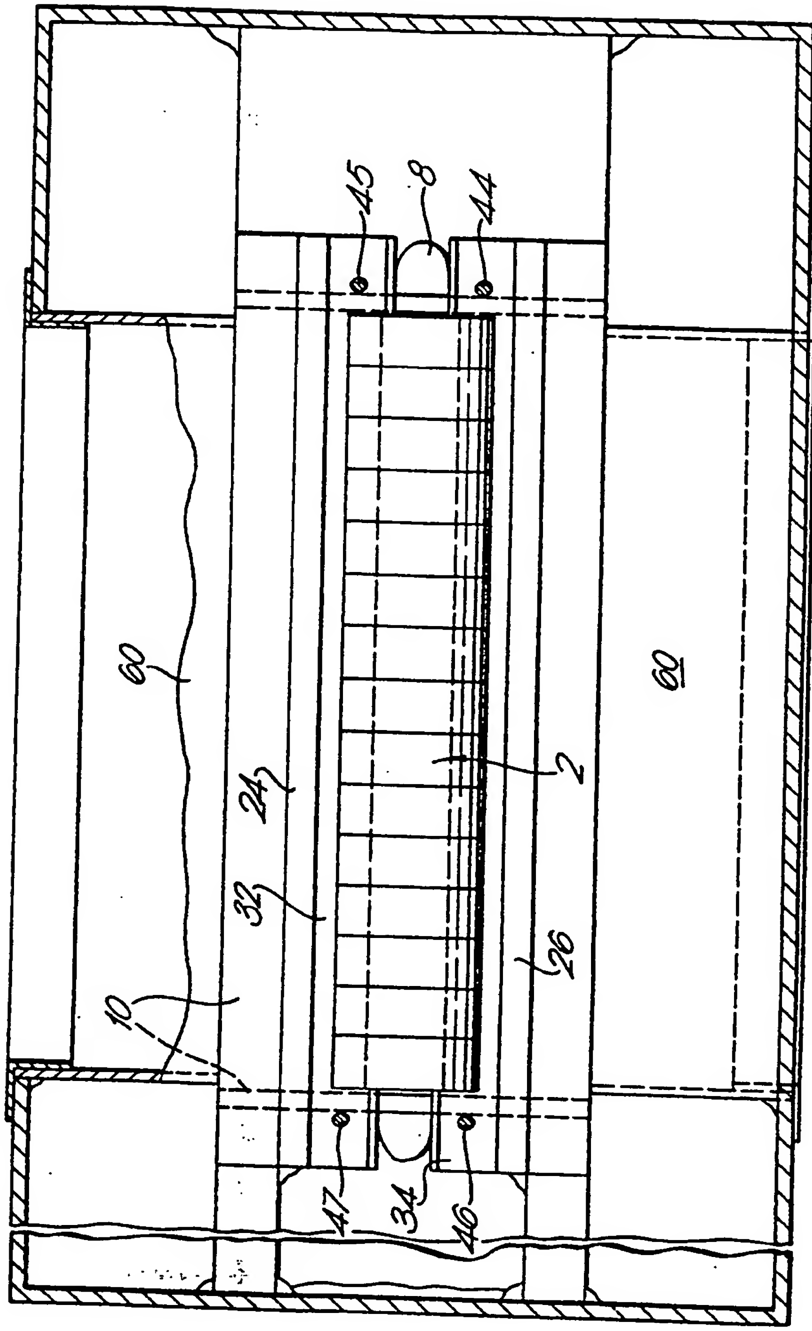

Fig. 5.

1,270,821 5 SHEETS

PROVISIONAL SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.

SHEET 4

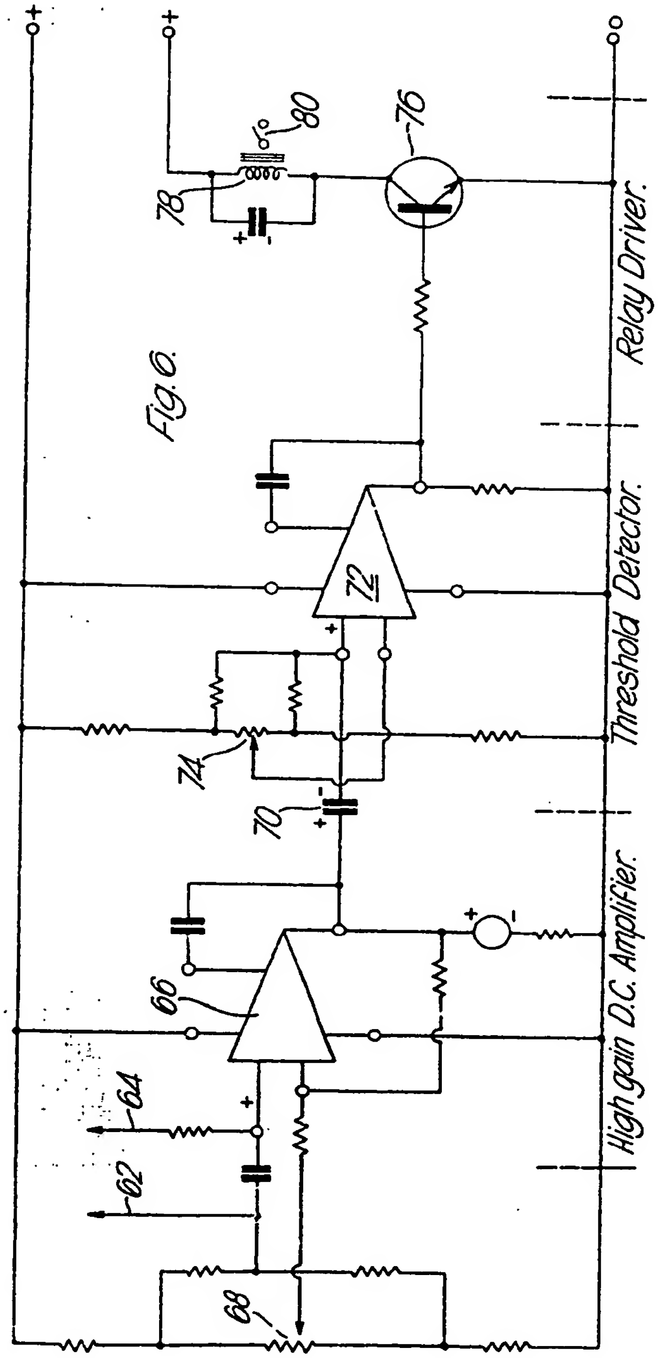

Fig. 6.

1,270,821 PROVISIONAL SPECIFICATION
5 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEET 5

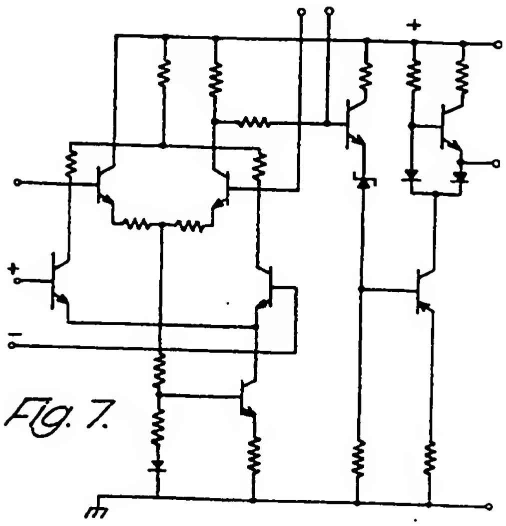

Fig. 7.

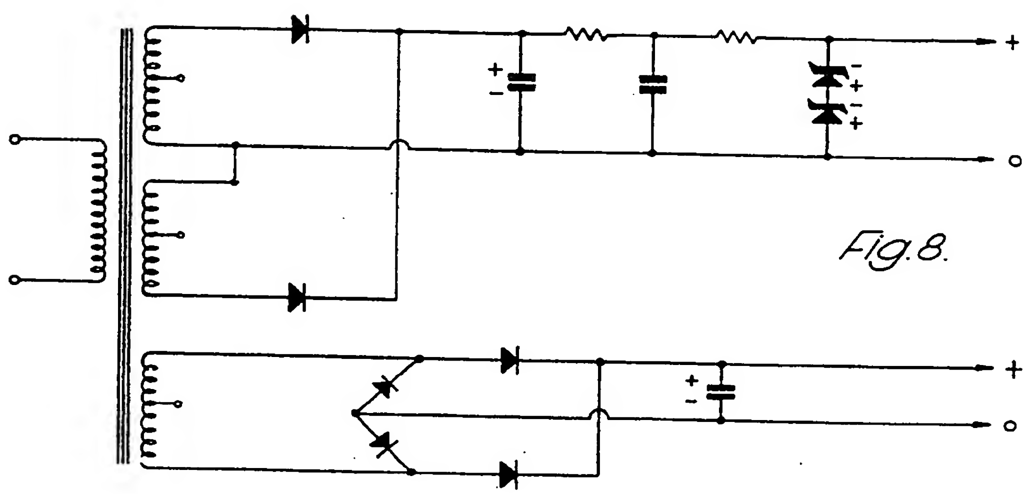

Fig. 8.

1,270,821 COMPLETE SPECIFICATION
1 SHEET
This drawing is a reproduction of the Original on a reduced scale.

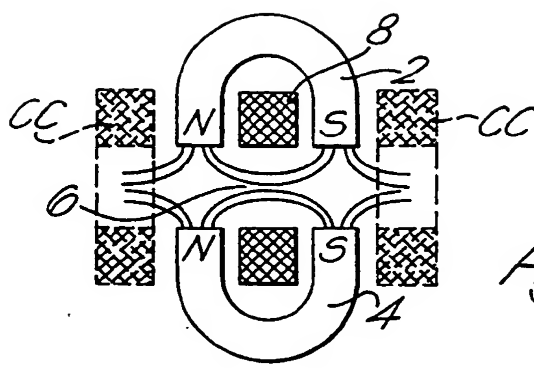

Fig.9.

This Page is Inserted by IFW Indexing and Scanning Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☑ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☑ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: ______________________

IMAGES ARE BEST AVAILABLE COPY.
As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.